February 12, 1857.

W. R. GROVE, Esq., V.P., in the Chair.

The following communications were read :—

I. "On the Photography of the Moon." By WILLIAM CROOKES, Esq. Communicated by Professor STOKES, Sec. R.S. Received December 16, 1856.

The subject of lunar photography is one which has engaged the attention of scientific men almost from the first announcement of the possibility of fixing the images in the camera. Owing to the extreme difficulty of satisfying all the conditions of the problem to be solved, there are few good photographs of the moon yet in existence. It was my good fortune in the autumn of 1855 to obtain several excellent pictures of this kind, and since these form the starting-point of the work which, by the assistance of a grant from the Donation Fund of the Royal Society, I have been pursuing during the greater part of the last year, a detailed account of the means employed for their production will not, I think, be considered out of place here.

The telescope in which these pictures were taken is the magnificent equatorial at the Liverpool Observatory. This, together with all the resources of the establishment, was placed at my disposal by my kind friend Mr. Hartnup, to whom it is but due to state, that, were it not for the invaluable assistance afforded me by his sterling advice as well as steady hand, the results would not have been worth keeping.

The mounting of the equatorial is quite unique; the polar axis and telescope together weigh about five tons, and whilst all parts are so truly and smoothly fitted that this enormous mass is moved equatorially by means of a small water-mill with such marvellous accuracy, that a star viewed through it appears absolutely stationary, its firmness is such that a hard blow against the side merely produces a scarcely perceptible momentary deflection. The object-glass is 8 inches in diameter, and has a sidereal focus of 12·5 feet—the diameter of the moon's image in this focus being about 1·35 inch.

The eyepiece was removed, and in its place the body of a small camera was attached, so that the moon's image might fall upon the ground glass or sensitive film in the usual manner. Much labour had been saved me in finding the true actinic focus, by several photographers of Liverpool, who were working for some time on the same subject when the British Association met in that city in 1854. They found that the object-glass had been over-corrected for the actinic rays—the plate being required to be placed at a distance of 0·8 of an inch beyond the optical focus: a few experiments were sufficient to enable me to verify this result.

During the time above referred to, and frequently since, Mr. Hartnup had taken many hundreds of pictures with chemicals recommended by various persons, but had not succeeded in obtaining a good negative at all, and not even a positive with a less exposure than from half a minute to a minute. As I succeeded in taking dense negatives in about four seconds, with the temperature of the room below freezing and the moon at a considerable distance from the meridian, and as I attribute the greater sensitiveness which I obtained to the great purity of the materials I employed, I think it right to give, after the mechanical arrangements are described, an account of the way in which these were prepared.

The clockwork movement was only sufficient to follow the moon approximately when on the meridian, but as the pictures were nearly all taken when she was some distance past the meridian, and when consequently the declination and atmospheric refraction were changing rapidly, it was necessary, notwithstanding the short time required to take the pictures, to correct for the imperfect motion of the telescope. This was done by means of slow-motion screws attached to the right ascension and declination circles, which are each 4 feet in diameter. The finder had an eyepiece with a power of 200 applied to it, having cross wires in its field.

The *modus operandi* of taking the picture was as follows:—The telescope having been moved until the moon's image was in the centre of the focusing glass, the water-mill was turned on and the dark slide containing the sensitive collodion plate was substituted for the ground glass. Mr. Hartnup then took his station at the finder, and, with a tangent rod in each hand, by a steady and continuous movement, kept the point of intersection of the cross wires stationary on one spot on the moon's surface.

When the motion was most perfectly neutralized, I uncovered the sensitive plate at a given signal and exposed it, counting the seconds by means of a loud-ticking chronometer by my side.

From the ease with which on my first attempt I could keep the cross wires of the finder fixed on one point of the moon by means of the tangent rods, I confidently believe that with the well-tutored hands and consummate skill which guided this noble instrument, the moon's image was as motionless on the collodion plate as it could have been were it a terrestrial object.

The negatives which I obtained by these means were exquisitely beautiful, and so minute that I could not obtain paper with a sufficiently fine surface whereon to print copies which would do them justice. It was evident that they would bear magnifying several diameters and still remain sharply defined. The expense of carrying out this design here stopped me, when by the kind advice of Professor Wheatstone I applied to the Royal Society, whose munificence has so frequently been the cause of bringing to a successful termination investigations of the highest importance.

A half-plate photographic combination of lenses, by Ross, was screwed the reverse way into a large sliding camera body 10 inches high by 11 inches wide, and capable of sliding from 18 inches to 3 feet long. At the end of the sliding body opposite to the lens, was a groove to admit either a focusing glass or a dark slide for the sensitive plate. A smaller camera body was screwed into the other end of the brasswork of the lens, having also a groove in front to admit of a sliding box capable of holding the small negatives. A reflector was placed in front of all, so arranged as to move in altitude round a centre, and, being fixed in any required position, to reflect the diffused light of the sky through the negative and lens parallel with the axis of the latter.

Preliminary trials showed me that there was no good gained by magnifying the small pictures more than about 20 times, as after that the individual parts begin to get confused and indistinct; this magnifying cannot, however, be effected at once. In the small negatives the lights and shades are the reverse of what they are in nature, consequently a print on paper therefrom gives the light and shade correct. A photographic copy of a negative, however, produces a positive by transmitted light, and a print from this would have the shadows light and the light parts dark; consequently, in magnifying a negative with the intention of still producing a negative, an intermediate transmitted positive must first be taken, and this in its turn magnified, when it will produce a negative.

The relative distances of the negative and focusing glass from the intermediate lens were so adjusted, that an image of the negative, enlarged to about two diameters, was thrown upon the ground glass, care being taken that the light from the sky was reflected parallel through the centres of the negative and lens by means of the mirror. The aperture of the lens was then stopped down to half an inch by means of a diaphragm, and the focus most carefully obtained by sliding the end of the large camera in or out. I found it necessary to verify this by experimental trials at different distances on each side of the observed focus, as it was difficult to judge accurately with the eye on the ground glass, owing to the roughness of the latter and the feebleness of the light.

A picture, or rather many pictures, were now taken, and the one which by transmitted light most truthfully resembled a paper print from the small negative was reserved for further magnifying. This was effected absolutely in the same manner as the former: the negative being removed and the positive being placed in its stead, a further magnifying gave a large-sized negative.

Although this process seems very simple, it is impossible to estimate the difficulties, unless by an actual repetition of the experiment, which I had to overcome before arriving at the beautiful result which I have the honour to lay before the Society. The double copying had a tendency to slightly exaggerate the effect of light and shade, and this could only be obviated by exposing the plates for such a time, that with the feeble light at my command it was verging on decomposition; particles of dust, too, seemed most pertinaciously to fix themselves on the prominent mountains, giving rise to craters where none should be; and even my finished pictures are not perfectly free from these faults, although each negative is the representative of a month's work and upwards of a hundred failures.

I doubt if much better photographs of our satellite can be taken by the way I have pursued. The future of lunar photography lies in another direction: the image must not be received on a sensitive plate and this copy submitted to an after process of magnifying. Defects quite imperceptible to the naked eye on the small negatives, are expanded into great blotches when magnified. In fact, upwards of a dozen seemingly equally good negatives with which I started, have, with but one or two exceptions, shown spots when enlarged.

The magnifying must be conducted simultaneously with the photographing, either by having the eyepiece on the telescope, or better still, by having a proper arrangement of lenses to throw a magnified moon image at once on the collodion. The difficulty of want of light could not be any objection, as supposing the enlarged image to be equal to those which I have now taken, that would be an increase of area of about twenty times, consequently 20×6 seconds, or 2 minutes, would represent the average time of exposure; a period which, even were it prolonged four or five times, would not then be too severe a tax upon a steady and skilful hand and eye.

Description of the Photographic Process.

The glass employed for taking the original negative of the moon, was that known as "extra white colour patent plate," that for the intermediate positives and large negatives was ordinary patent plate. Cleaning the surface, which is an operation of especial importance, was effected in the following manner.

The glasses were dipped into and then well rubbed over with a hot solution of caustic potassa; then, after washing with water, they were transferred to hot nitric acid (one part strong acid to three of water), where they were allowed to remain for about half an hour.

A piece of soft wash-leather was plentifully rinsed, first in a warm dilute solution of carbonate of soda, afterwards in clean water, and then well wrung until all the superfluous water was squeezed out. The glass plates were taken from the nitric acid and rinsed in abundance of clean water, and then rubbed well on every part with the damp leather. This removed most of the superficial moisture; and the final drying was effected by means of another piece of wash-leather, prepared the same as before, but allowed to become perfectly dry.

Just previous to using, the plates, held in a pneumatic plate-holder, had the last polish given to them by briskly rubbing with a warm piece of fine diaper (which had also been previously washed in soda and water, and then well rinsed and dried) until the moisture condensed from the breath evaporated evenly and uniformly, especially guarding against the slightest contact between the surface of the glass and the fingers.

The plate was now held with its clean side downward until the collodion was about to be poured on, and every particle of dust (which was easily seen by bringing the source of light, the under surface of the plate and the eye, nearly in the same line) was gently wiped off by passing a warm piece of fine cambric lightly across.

Care was also taken to have the atmosphere of the room as free as possible from floating particles, and the dried collodion usually adhering to the neck of the bottle was scrupulously removed.

The collodion was poured on and the plate rendered sensitive in the usual way. As the temperature both of the equatorial and operating rooms was seldom far from the freezing-point, the great diminution of sensitiveness, which that circumstance would have occasioned, was obviated by having the nitrate of silver bath and developing solution warmed to about 30° C., and also by slightly warming the plates before using. The source of light was a fishtail gas burner in the outer room, and shining close to the orange glass window of the dark room.

The soluble paper for the collodion was prepared in the following manner:—a mixture was made of

	sp. gr.	
Commercial nitrous acid	1·43	4 fluid ounces.
Commercial nitric acid........	1·37	4 ,,
Sulphuric acid	1·82	8 ,,

When the temperature of the mixture had cooled down to 50° C., one sheet of Swedish filtering-paper, torn up into small pieces, was completely immersed in the mixture, and allowed to remain therein for about half an hour. It was then thrown into a large pail of water, and the paper removed and placed on a sieve under a running tap for a quarter of an hour; after washing in very dilute solution of ammonia and then in plenty of water, the paper was pressed between the folds of a cloth, and then allowed to dry spontaneously in the air.

The collodion was made with—

Ether, sp. gr. ·725 (previously freed from acid by rectification from dry caustic potassa)	5 fluid ounces.
Absolute alcohol	3 ,,
Soluble paper (dried at 100° C.)	50 grains.
Iodide of cadmium (*pure*)........	30 ,,

The alcohol and ether were mixed together, and then the paper and iodide of cadmium were added: they dissolved in a few minutes with a little shaking. As soon as the solution was complete, it was allowed to stand for twenty-four hours, and then half of the clear supernatant fluid was decanted carefully into a clean well-stoppered bottle for use. I believe that collodion prepared in this way will remain uniform from one year's end to another.

The nitrate of silver bath was made by dissolving 1 ounce of crystallized nitrate of silver, perfectly pure and neutral, in 2 ounces of water, then, with constant stirring, adding a solution of 4 grains of iodide of cadmium in 1 ounce of water, and a quarter of an ounce of the above iodized collodion, and water to make up the volume to 10 ounces. This was allowed to stand for a few hours at a temperature of about 25° C., and then filtered from the undissolved iodide of silver and precipitated paper. A glass bath was used in preference to gutta percha, and, as above stated, it was heated to 30° C. when used.

The developing solution consisted of—

Pure pyrogallic acid	8 grains.
Crystallized citric acid	16 ,,
Water..........................	8 fluid ounces.
Alcohol	½ ,,

This developing solution is very slow in its action, 15 to 20 minutes being frequently required, but it ultimately produces negatives of such vigour and freedom from stains, that I much prefer it to the usual formula.

The fixing solution employed was the ordinary nearly saturated solution of hyposulphite of soda. After its employment the pictures were well and carefully washed in warm water, dried before a fire, and, after scratching the description or name on a corner, varnished with the usual solution of amber in chloroform.

The subsequent operation of printing is so easily performed, and has been so fully described by persons of more experience than myself, that any further allusion to it will be needless.

Appendix.

Besides the pictures taken in America—which are almost valueless as moon maps, as the sides are reversed in the copying from the daguerreotype plate upon which they were originally taken,—the moon has been photographed by Professor Phillips, Father Secchi, MM. Bertsch and Arnauld, several Liverpool photographers, and Mr. Hartnup and myself. It is interesting and instructive to compare among themselves the means employed and the time occupied in taking the impression on these several occasions.

Professor Phillips's telescope has a sidereal focus of 11 feet, and an aperture of $6\frac{1}{4}$ inches; consequently the brilliancy of the moon's image in its focus is augmented 26 times over what she appears to the naked eye. The average time occupied for the collodion plate to receive the impression was about 3 minutes.

Father Secchi's telescope having a sidereal focus of 18 times its aperture, the moon's image was intensified 37·8 times, and the time required for the impression was an average of 6 minutes.

M. Porro's glass of 49 feet sidereal focus and 20 inches aperture, gave a moon image 12·3 times brighter than she appeared to the naked eye, and the average time of taking the picture was 17 seconds.

Mr. Hartnup's telescope being $12\frac{1}{2}$ feet focus and 8 inches aperture, augments the intensity of the moon's image at its focus 35·1 times. The time which was required for the photograph of our satellite to be taken, on the occasion of the meeting of the British Association at Liverpool in 1854, was about 2 minutes; and under the same circumstances we ourselves succeeded in obtaining perfect and intense negatives in 4 seconds. These, however, were taken under very unfavourable circumstances, the temperature being below the freezing-point, and the moon at a considerable distance from the meridian, which necessarily caused both a diminution of the light and also a diminished sensitiveness of the collodion film.

The rapidity with which the above pictures were taken may be better understood by comparing them with those of terrestrial objects under similar circumstances. According to Herschel*—

"The actual illumination of the lunar surface is not much superior to that of weathered sandstone rock in full sunshine. I have frequently compared the moon setting behind the grey perpendicular façade of the Table Mountain, illuminated by the sun just risen in the opposite quarter of the horizon, when it has been scarcely distinguishable in brightness from the rock in contact with it. The sun and moon being nearly at equal altitudes, and the atmosphere perfectly free from cloud or vapour, its effect is alike on both luminaries."

Thus by comparing the Liverpool object-glass as to power with our ordinary camera lens, its focal length being nearly 19 times the aperture, and the moon's image being copied by its means in 4 seconds, we find that it is equivalent to copying sandstone illuminated by the sun in 4 seconds with a lens $4\frac{1}{2}$ inches focus and a little less than $\frac{1}{4}$ inch diaphragm; or with a compound lens having an aperture of one inch, and the same focal length, in a quarter of a second.

II. "Researches on the Reproductive Organs of the Annelids." By Thomas Williams, M.D., F.L.S., Physician to the Swansea Infirmary. Communicated by Thomas Bell, Esq., F.R.S., P.L.S. &c. Received December 30, 1856.

(Abstract.)

In this paper the author seeks to establish the following general proposition, viz. that there prevails throughout the Actiniadæ, Echinodermata, Rotifera and Annelida, a special organ, which, under different phases, subserves different functions, which is essentially *identifiable* under every modification, reducible to the same type, and which constitutes the *root* of the Reproductive system in these families. To this special organ he proposes to apply the provisional

* Herschel's Outlines of Astronomy, page 249.